AD-A037 687   NAVAL AIR TEST CENTER   PATUXENT RIVER MD   F/G 14/2
                MAXIMIZING FLIGHT FIDELITY; INTEGRATION OF NAVAL AIR TEST CENTE--ETC(U)
                MAR 77   R T GALLOWAY

UNCLASSIFIED   NATC-TM-76-4-SA   NL
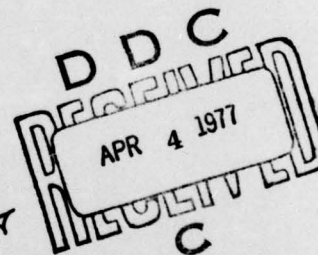
1 OF 1
AD
A037 687

END
DATE
FILMED
4-77

TM 76-4 SA

Technical Memorandum

MAXIMIZING FLIGHT FIDELITY;
INTEGRATION OF
NAVAL AIR TEST CENTER
CAPABILITIES INTO THE
PROCUREMENT OF
MAJOR AVIATION TRAINING DEVICES

Mr. R. T. Galloway
Project Engineer

Strike Aircraft Test Directorate

16 March 1977

DDC

APR 4 1977

C

DEPARTMENT OF THE NAVY

NAVAL AIR TEST CENTER

NAVAL AIR TEST CENTER
PATUXENT RIVER, MARYLAND

TM 76-4 SA

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER NATC-TM-76-4-SA	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) MAXIMIZING FLIGHT FIDELITY; INTEGRATION OF NAVAL AIR TEST CENTER CAPABILITIES INTO THE PROCUREMENT OF MAJOR AVIATION TRAINING DEVICES		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) R. T. GALLOWAY		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS STRIKE AIRCRAFT TEST DIRECTORATE PATUXENT RIVER, MARYLAND 20670		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS NAVAL AIR TEST CENTER NAVAL AIR STATION PATUXENT RIVER, MARYLAND 20670		12. REPORT DATE 16 Mar 1977
		13. NUMBER OF PAGES 15
14. MONITORING AGENCY NAME & ADDRESS(if different from Controlling Office) Technical memo.		15. SECURITY CLASS. (of this report) UNCLASSIFIED
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

FLIGHT TESTING   BASELINE DATA
FLIGHT FIDELITY
OPERATIONAL FLIGHT TRAINERS
WEAPONS SYSTEM TRAINERS
SIMULATOR

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Flight test engineers and test pilots from NATC have recently become involved with flight fidelity testing of Operational Flight Trainers and Weapons System Trainers. The purpose of this flight fidelity testing is to determine if the simulator flying qualities, performance, and systems operation are quantitatively representative of the design basis aircraft. Initial NATC involvement in Operational Flight Trainers and Weapons System Trainers acceptance testing commenced in the final acceptance test period which resulted in considerable delays since extensive software changes were sometimes required to correct flight fidelity deficiencies. Therefore, a new Navy test policy for Operational Flight

DD FORM 1 JAN 73 1473   EDITION OF 1 NOV 65 IS OBSOLETE

246 750

20.

Trainers and Weapons System Trainers acceptance was developed by representatives of NATC, Naval Training Equipment Center, and NAVAIR. This paper outlines the major elements of the new policy whereby NATC participation is included much earlier in the Operational Flight Trainers and Weapons System Trainers procurement cycle to monitor development and provide flight test assistance as soon as practicable. In addition, NATC flight fidelity test methods are discussed in general.

PREFACE

This Technical Memorandum contains a paper which was presented at the Ninth NAVTRAEQUIPCEN/INDUSTRY Conference in Orlando, Florida, on 9-11 November 1976. The paper summarizes the NATC role that has evolved to date for achieving maximum flight fidelity in Operational Flight Trainers and Weapons System Trainers. The evolution of this role occurred during flight fidelity evaluations managed by NAVAIR (AIR-413) and the Naval Training Equipment Center.

APPROVED FOR RELEASE

RADM J. H. FOXGROVER, USN
COMMANDER, NAVAL AIR TEST CENTER

INTRODUCTION

1. Flight test engineers and test pilots from NATC have recently become involved with evaluating the flight fidelity of new Operational Flight Trainers (OFT) and Weapons System Trainers (WST) being procured by the U. S. Navy and Marine Corps. The purpose of all NATC flight fidelity evaluations is to answer the question: Does this Device fly like the airplane? To formulate such an answer, these engineers and test pilots compare OFT/WST simulated flying qualities, performance, engine systems, and weapons/avionics systems characteristics to those of the actual airplane. The major component of NATC testing is the application of quantitative test techniques to identify fidelity deficiencies and eliminate dependence on purely subjective analysis. The quantitative test techniques applied here are generally identical to those routinely utilized by NATC during aircraft flight test programs. The extent of NATC involvement in OFT/WST testing is outlined in Appendix A.

NATC TEST BACKGROUND

2. The type of airplane testing conducted by NATC is definitely germane to simulator fidelity testing. In brief, the mission areas of NATC that are relevant to OFT/WST fidelity include testing of aircraft flying qualities, performance, carrier suitability, propulsion systems, and mission systems (avionics, ECM, radar, reconnaissance sensors) for all Navy and Marine Corps fixed wing, rotary wing, and VSTOL aircraft. The normal NATC cycle begins with NPE's conducted at the contractor's facility at various stages of the aircraft and system development. The purpose of these NPE's is to discover serious deficiencies early enough to allow correction by the contractor without delay in delivery to the fleet. The guidelines for such testing are contained in the demonstration specification, MIL-D-8708, which calls for five NPE phases with the first phase occurring within 90 days after the first flight of the new aircraft. After the NPE phases of testing are complete, fleet representative aircraft are evaluated at NATC with contractor demonstrations of contract guarantee items and Navy BIS Service Acceptance Trials. Finally, a follow-on technical evaluation is usually conducted at NATC to document pertinent characteristics. Such a test process usually results in large quantities of data at NATC concerning airplane and system characteristics. Unfortunately, time and money constraints generally limit published data to documentation of deficiencies and flight characteristics at the edges of the flight envelope. As a result, the mid-envelope characteristics needed to assess OFT/WST flight fidelity remain undocumented and further flight tests are required. Data availability and flight test requirements are discussed in depth in later paragraphs.

OFT/WST TEST POLICY

3.   The initial role of NATC in OFT/WST testing was only to provide airplane data in areas otherwise unavailable to the simulator contractor.   It soon became apparent that NATC airplane test techniques were as useful for quantifying OFT/WST deficiencies as they were in the airplane.   Unfortunately, these initial efforts by NATC occurred during final acceptance phases of each OFT/WST and considerable delays were incurred since extensive software changes were usually required by the contractor to correct the flight fidelity deficiencies.   For instance, in-plant acceptance of the T-2C OFT (Device 2F101) was delayed by approximately 6 months primarily for flight fidelity problems and the A-4M OFT (Device 2F108) in-plant acceptance was similarly delayed by 4 months.   In order to eliminate these costly delays, NATC simulator project personnel conferred with representatives of the Naval Training Equipment Center (NTEC) and NAVAIR to develop the most effective means of incorporating NATC into the procurement cycle of new OFT's and WST's so that flight fidelity would be assured and realistic development and testing schedules could be written.   The major elements of the Navy test policy so developed are outlined below.   It should be noted that the NATC OFT/WST project engineer/test pilot team participates only in as many of the tasks as required by NAVAIR.   The major elements are:

   a.   Establish liaison with appropriate NAVAIR and NTEC personnel.

   b.   Assist in specification preparation, proposal evaluation, and monitor the contractor's development effort, where possible, to assure flight fidelity.

   c.   Provide NATC-developed flight test data as needed for OFT/WST development and as standard for measurement of flight fidelity.

   d.   Conduct NPE's of the OFT/WST during development.

   e.   Participate in in-plant acceptance testing.

   f.   Provide engineering and test pilot assistance in adjusting hardware and software to achieve proper flight fidelity.

   g.   Participate in on-site acceptance to validate OFT/WST flight fidelity.

   h.   Participate in validation of subsequent OFT/WST units during in-plant and on-site acceptance.

   i.   Conduct follow-on evaluations of update (ECP) efforts affecting flight fidelity.

   j.   Prepare reports documenting flight fidelity of the OFT/WST.

4.   The major innovations to the OFT/WST procurement process are items c. and d. from the above list. The advantage of incorporating NATC-developed flight test data as early as possible to describe the characteristics to be simulated is obvious. The introduction of the NPE concept to simulator flight fidelity testing is a direct adaptation of U.S. Navy aircraft procurement policy. The advantage of early deficiency detection through brief evaluations of the OFT/WST during the development phase is that more time is available to the contractor to develop improvements by obtaining more data and to refine the hardware and software. To date, the only simulator we have been able to evaluate under the NPE concept was the A-7E WST, Device 2F111, in January 1975, where NATC conducted a 4-day period of tests of flying qualities and performance. This evaluation was possible only because of a gap in the development process (the radar simulation equipment was not ready) but it did reveal some problem areas in time to obtain appropriate data for clarification of these problems before acceptance testing began. For the future, similar NPE efforts are planned for the E-2C OFT (Device 2F110) and EA-6B WST (Device 2F119). The number of NPE's required for any particular OFT/WST will vary with the complexity of the simulator (OFT vs WST) and the development progress (readiness of avionics, motion system, etc.). Regardless of the number of NPE's, each NPE is intended to be a 3 to 5-day evaluation on a frozen configuration at significant milestones during the development phase.

OFT/WST TEST EXPERIENCE

Baseline Data Accumulation

5.   Regardless of what point we enter the OFT/WST development cycle, the NATC project team always begins baseline data accumulation by searching out appropriate published and unpublished flight test data. If the airplane being simulated is still being tested in the normal NATC test cycle, then usually a wealth of useful but unpublished data is available. This was the case during acceptance testing of the S-3A WST and the F-14A OFT. However, the approach of "piggybacking" OFT/WST test requirements with airplane development testing produces only limited results since data requirements may differ and airplane program requirements take priority over simulator requirements in competing for expensive flight time in a fully instrumented airplane.

6.   For most of our OFT/WST programs, insufficient data exist so that additional flight tests are required to build the required data base, and this is generally done with uninstrumented fleet airplanes. However, data gathering in fleet aircraft holds several advantages in that the fleet airplane is usually more representative of the simulator configuration than the test articles at NATC. In addition, testing of several fleet airplanes allows documentation of average airplane characteristics, particularly with respect to control system characteristics. Normally, about 15 hours of flight time are required to build an adequate data base and tests conducted include documentation of mid-envelope airframe and engine characteristics, response to small inputs in all axes, and open loop characteristics at high angles of attack or during configuration changes. Use of relatively simple

instrumentation, such as hand-held force gauges, stop watches, tape measures, and production cockpit instruments, has proven to be adequate and allows considerable flexibility in going from one cockpit to another, be it airplane or simulator. The use of such austere instrumentation also permits rapid data generation in the airplane should significant gaps or questionable areas arise during simulator testing. Also, the use of identical instrumentation in the airplane and simulator enhance the repeatability of test techniques and data.

7. We do not, however, consider the extensive use of hand-held instrumentation a panacea. If additional meaningful test data from an instrumented airplane becomes available during a simulator test period, we do not hesitate to use it. Of course, it would be far more desirable if such data were available in advance so that a contractor could detect a fidelity problem before Navy testing commences. The effort is underway within the Navy to apprise aircraft program managers of simulator data requirements so that funding is available to publish all pertinent data and so that aircraft test programs can include maneuvers for simulator needs along with the usual airplane specification test requirements. Hopefully, this effort will lead to more complete documentation of airplane characteristics in time to aid a simulator contractor during his development phase.

SIMULATOR TESTING

8. Flight fidelity tests on an OFT/WST are conducted merely by repeating airplane test techniques at the baseline data test conditions. It is not desirable for the NATC tests to adhere to some prearranged detailed outline of tests, such as the Acceptance Test Procedures Report, since the test techniques utilized by a test pilot cannot always be described adequately in a step-by-step manner to enable a layman to obtain repeatable results. It is preferable that flying qualities tests, such as required to assess maneuvering longitudinal stability, be left to a trained test pilot.[1] In addition, fidelity problems may require that a majority of the NATC testing be concentrated in one area, such as lateral control sensitivity, where additional airplane flight tests might be required for data and the test conditions would not be defined to an exact gross weight or airspeed until that time. For this reason, a general outline of the tests to be conducted and the flight envelope to be investigated is considered the most meaningful planning document that NATC can provide a simulator contractor in anticipation of our flight fidelity testing, and we have provided such an outline prior to testing when requested. A typical general test outline is presented in Appendix B.

9. The bulk of NATC simulator testing is conducted on the fixed base cockpit without motion or visual cues, since the primary flight fidelity goal is to have the airplane response as seen on the simulator cockpit instruments and controls match the response as seen on the airplane cockpit instruments and controls. Obviously, the OFT/WST flight dynamics (hardware and software) must match on this basis before a meaningful evaluation of the motion and visual cues can be conducted.[2]

[1]U. S. Naval Test Pilot School Fixed Wing Stability and Control Manual, of 1 January 1975, U. S. Naval Air Test Center, Patuxent River, Maryland.

[2]Improving the Flight Fidelity of Operational Flight/Weapon System Trainers, Technical Memorandum TM 75-1 SA, 7 October 1975, by M. D. Hewett and R. T. Galloway, Naval Air Test Center, Patuxent River, Maryland.

10. Another facet of flight fidelity testing is pilot "memory." During our evaluations, we have found that it doesn't take a test pilot in the simulator very long to forget subtle airplane characteristics. For instance, during tests of the S-3A WST with the VITAL III visual system, an experienced NATC S-3A test pilot became adapted to the simulation within only 30 minutes; that is, during his first 30 minutes of flying landing approaches in the WST, he used normal airplane pilot technique and he encountered extreme difficulty in making smooth approaches. Thereafter, he learned to compensate for the fidelity problems, his approaches became smooth, and his qualitative analyses of the simulation lost considerable value. The only way to alleviate such a problem is for the pilot to periodically fly the airplane during the OFT/WST test program, especially since there are still many subtle flight characteristics, such as closed loop flying qualities in the approach, which elude quantification and can only be defined properly by refreshed pilot opinion. This practice of pilot refamiliarization was utilized by the NATC test teams, particularly during the extensive evaluations conducted on the T-2C OFT and the TA-4J OFT where considerable flight time was graciously provided by the Naval Air Training Command.

DEFICIENCY RESOLUTION

11. When the NATC test team encounters a flight fidelity deficiency during acceptance testing, the problem is described with as much data as possible in the deficiency report. The intention is to describe the problem well enough to permit the contractor to develop corrections without the presence of the NATC test team. The workload of the NATC test pilots and engineers always includes other projects with varying priority requirements so that extensive tweaking periods at the simulator are a luxury in which we cannot indulge. Therefore, the NATC OFT/WST test team endeavors to assist the contractor as much as possible in isolating a flight fidelity problem, but it must be recognized that presence of the NATC test team at the simulator is of necessity limited to relatively short intervals.

TYPICAL FIDELITY PROBLEM AREAS

12. The type of testing provided by NATC can be illustrated by discussing typical fidelity problem areas encountered in our OFT/WST testing. One of the most critical problem areas we have encountered is in control loading fidelity where control stick breakout forces, damping, and centering characteristics are found to be unrepresentative of the airplane. Many times this is due to the use of control system design data vice actual airplane test data, and once the correct data are made available, only simple adjustments are necessary. However, some control loading designs, particularly the electro-hydraulic type, seem to require extensive care to retain alignment which is undesirable from a maintenance standpoint. Obviously, poor control loading fidelity can seriously degrade an otherwise excellent flight dynamics software model.

13. The flight dynamics software model suffers in fidelity from dependence on wind tunnel data, as everyone knows. Therefore, the NATC test team devotes considerable attention to areas, such as the high angle of attack regime, since baseline data are usually sketchy but NATC test pilots have extensive flight test experience in this regime. In most cases, a representative simulation of airplane stall characteristics, including motion base buffet cues, can be developed by an experienced test pilot working in conjunction with contractor software experts. In addition, many flight fidelity problems are compounded by software shortcuts, such as low computation rates to save computer time and delayed output of computed variables such as roll angle to the pilot's gyro. Admittedly, software architecture is out of the NATC realm of expertise but these problems are mentioned only because we can recognize their effects on fidelity when trying to assist the contractor in identifying the source of a flight fidelity problem. Finally, the refinement of visual scene response has always proven to be difficult, especially for closed loop tasks such as landing approaches. Some success has been achieved, particularly with the TA-4J OFT at NAS Kingsville and the S-3A WST/VITAL III at NAS Cecil Field, by careful adjustment of appropriate software terms while repeating a well defined task until a representative simulation is achieved.

SIMULATOR CERTIFICATION

14. As the dependence on OFT's and WST's increases in maintaining pilot proficiency in the U.S. Navy, so will the demand that adequate fidelity be developed and retained in these simulators. Any future simulator certification programs should definitely include flight fidelity evaluations by NATC test pilots and engineers. Such evaluations would be similar to the brief on-site validation tests currently conducted when a new device is first installed, but they would serve to confirm adequate fidelity or help define any new problem areas which might have crept in due to control loading degradation or inadvertent software changes. Our experience with the TA-4J OFT and the S-3A WST showed that these problems do occur. Therefore, the use of quantitative testing by an NATC project team, particularly in flying qualities evaluations, is just as necessary for certification as in acceptance testing.

CONCLUSION

15. In summary, the utilization of NATC flight test data and quantitative test techniques in Operational Flight Trainers and Weapons System Trainers flight fidelity evaluations has increased steadily since 1973. An orderly process for including NATC inputs into the Operational Flight Trainers and Weapons System Trainers procurement process as early as possible has been developed in conjunction with NAVAIR and the Naval Training Equipment Center. An effort is underway to include simulator data requirements with existing aircraft testing requirements for future airplane and Operational Flight Trainers and Weapons System Trainers procurements. Current NATC flight fidelity test programs have shown that meaningful data can be obtained with simple hand-held instrumentation, that the test pilot must frequently refamiliarize himself with subtle airplane characteristics during the simulator evaluation period, and that NATC evaluation periods are best conducted over brief periods beginning sometime in the development phase. Hopefully, such extensive efforts to achieve maximum flight fidelity will increase the training value of Operational Flight Trainers and Weapons System Trainers or at least make the use of such devices more meaningful to Naval aviators than in the past.

NATC OFT/WST Test Experience

Device	Test Scope	Test Period
T-2C OFT (2F101)	Acceptance testing (Units 1-7)	1973-1975
TA-4J OFT (2F90)	Fidelity improvement for use with visual system	1974-1975
S-3A WST (2F92)	a. Acceptance testing (Units 1 and 2) b. VITAL III retrofit and WST aero update (Unit 2) c. Acceptance testing (Units 3-5)	1974-1975 1975-1976 1976-1977
F-14A OFT (2F95)	Aero updates plus retrofit of VITAL II visual evaluation (Units 2, 3, and 4)	1974-1976
A-7E NCLT (2F103)	a. Fidelity evaluation b. Aero update evaluation	1974 1976
A-7E WST (2F111)	a. NPE (Unit 1) b. Acceptance testing (Units 1 and 2)	1975 1975-1976
A-4M OFT (2F108)	Acceptance testing (Units 1 and 2)	1975-1976
KC-130F OFT (2F107)	Acceptance testing	1975-1976
SH-2F WST (2F106)	a. Acceptance testing (Units 1 and 2) b. VITAL III visual retrofit	1975-1976 1976
F-4J WST (2F88)	Acceptance testing (USMC)	1976
EA-6B WST (2F119)	a. Proposal evaluation b. Monitor development, baseline data generation c. Testing (NPE, Acceptance)	1975 1976 1977-1978
A-6E WST (2F114)	a. Detail specification comment b. Baseline data generation c. Acceptance testing (Units 1 and 2)	1974 1976-1977 1977-1978

FUTURE PROGRAMS
 	
  E-2C OFT (2F110)
  F-14A WST (2F112)
  CH-46E OFT (2F117)
  ACMT (2E6)
	a. Monitor development
	b. Testing (NPE, Acceptance)
		1976-
		1977-

TYPICAL FLIGHT FIDELITY TEST MATRIX

The majority of the test conditions are in the Cruise configuration at medium altitudes (10,000 - 15,000 ft (3 050 - 4 570 m)) to substantiate mid-envelope flight fidelity, but additional tests are conducted at low and high altitudes. Landing configuration tests are conducted at or below 5,000 ft (1 520 m), except stalls and rolls which are done at 10,000 ft (3 050 m). Flying qualities tests are conducted as appropriate with control augmentation and/or stability augmentation on and off. Specific tests for motion base cues include qualitative evaluation of acceleration cues in normal flight and motion cues at stall, and quantitative measurement of buffet boundaries. The following outline presents flying qualities, performance, and systems operation of primary interest for fixed base tests. Specific values for airspeeds, gross weights, CG, and loading are selected to complement existing data.

Test	Parameters of Interest
Control System Mechanical Characteristics	Breakout, including friction, centering, freeplay, control system oscillations.
Static Trim Points	Trim settings, power settings, angle of attack (AOA). In landing configuration, variation of trim airspeed and trim setting with gross weight at on-speed AOA.
a. Static Longitudinal Stability b. Maneuvering Longitudinal Stability	Longitudinal stick position and force gradients, AOA gradients. Flight path stability in landing configuration.
Dynamic Longitudinal Stability	Frequency and damping of short period and phugoid modes from free response to longitudinal inputs.
Trim Changes	Effects of landing gear, flaps, power changes, speedbrakes, runaway trim (open and closed loop).
Longitudinal Control Effectiveness	Nose wheel lift-off, airplane rotation characteristics.
Dutch Roll	Period and damping from rudder doublet inputs.
Static Lateral-Directional Stability	Sideslip, bank angle, lateral stick force, and rudder position from steady heading sideslips.
Lateral Control Effectiveness	Full and partial deflection rolls. Measure time for given bank angle change.
Instrument Tracking Tasks	Ability to command and hold a given g or attitude. Also, heading displacement during roll-in and roll-out of turns. AOA indicator response to sinusoidal longitudinal stick inputs.
Stall Characteristics	Variation of airspeed, longitudinal stick position and force, rate of climb/descent with AOA during 1 g stall approaches.
Level Accelerations, Decelerations	Time history of airspeed (V_{min} to V_{max}). Speedbrake in and out for decelerations.
Climb Performance	Rate of climb, fuel flow variation with altitude.
Engine Systems	Ground and air starts, response to rapid full and partial throttle inputs.
Avionics/Weapons Systems	Functional checks.

DISTRIBUTION:

NAVAIRTESTCEN (CT02)	(1)
NAVAIRTESTCEN (CT03)	(1)
NAVAIRTESTCEN (CT08)	(1)
NAVAIRTESTCEN (SA01)	(5)
NAVAIRTESTCEN (SY01)	(2)
NAVAIRTESTCEN (RW01)	(2)
NAVAIRTESTCEN (AT01)	(2)
NAVAIRTESTCEN (TP01)	(2)
NAVAIRTESTCEN (TS01)	(2)
NAVAIRTESTCEN (CS01)	(2)
DDC	(12)